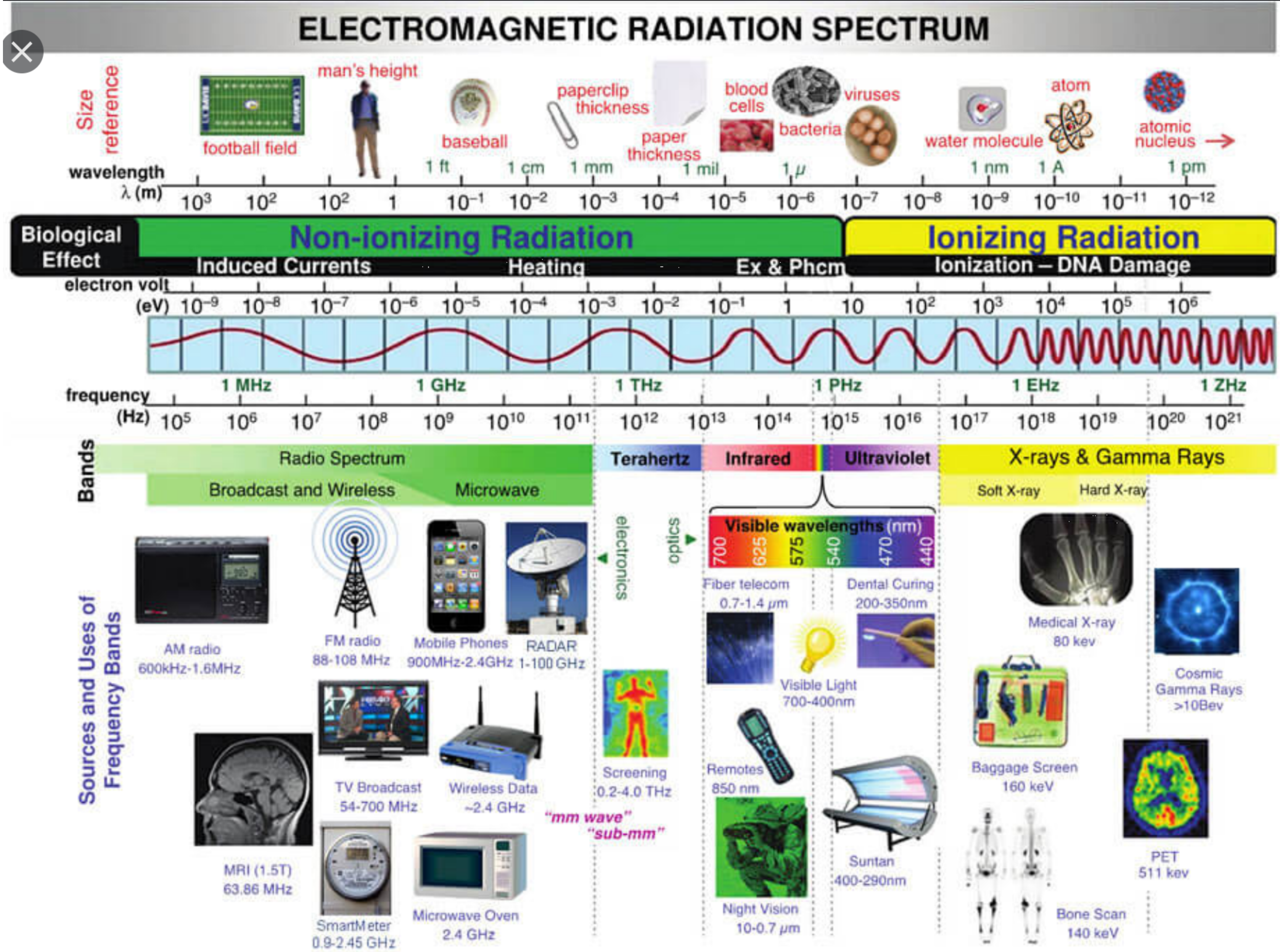
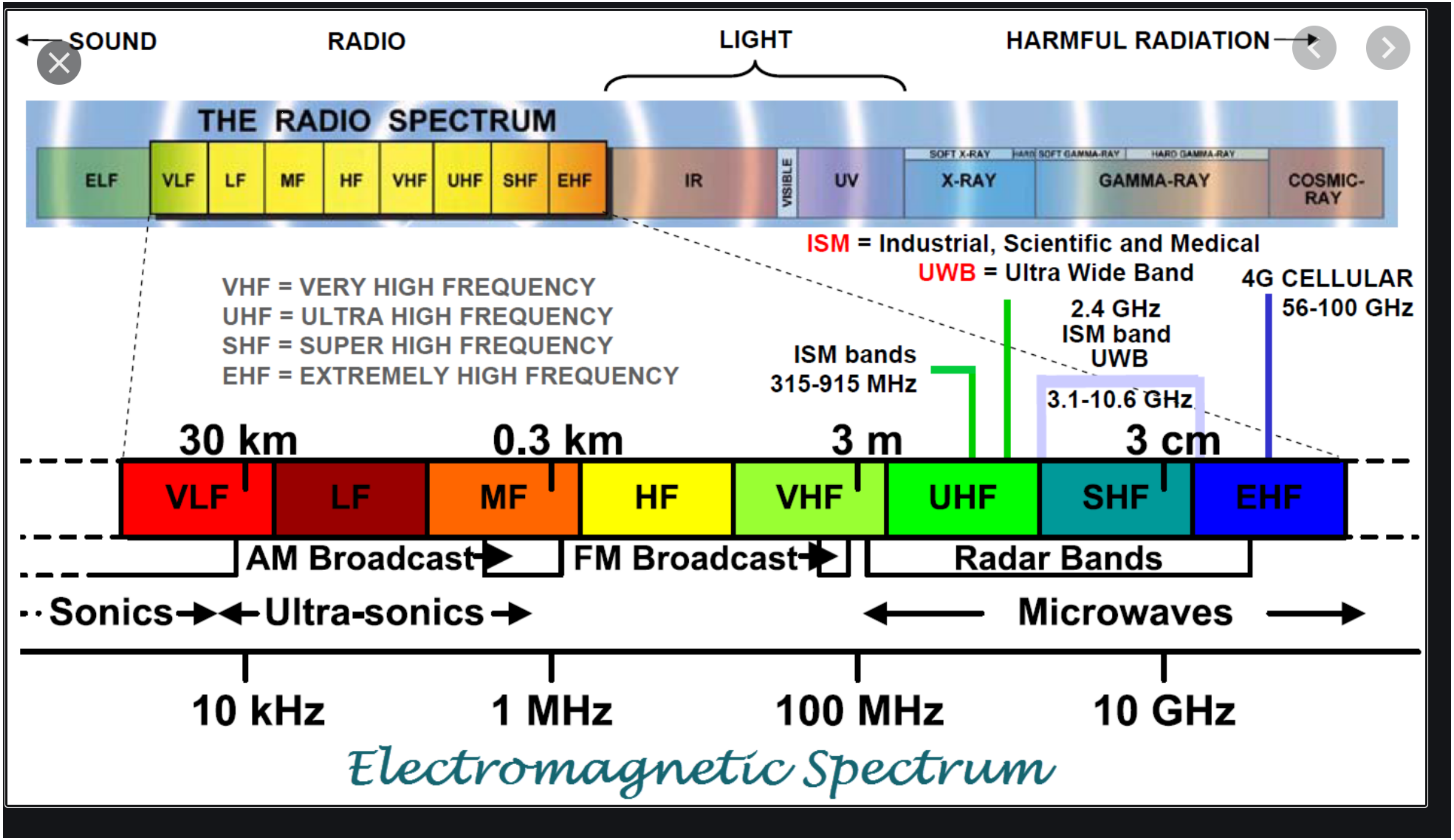
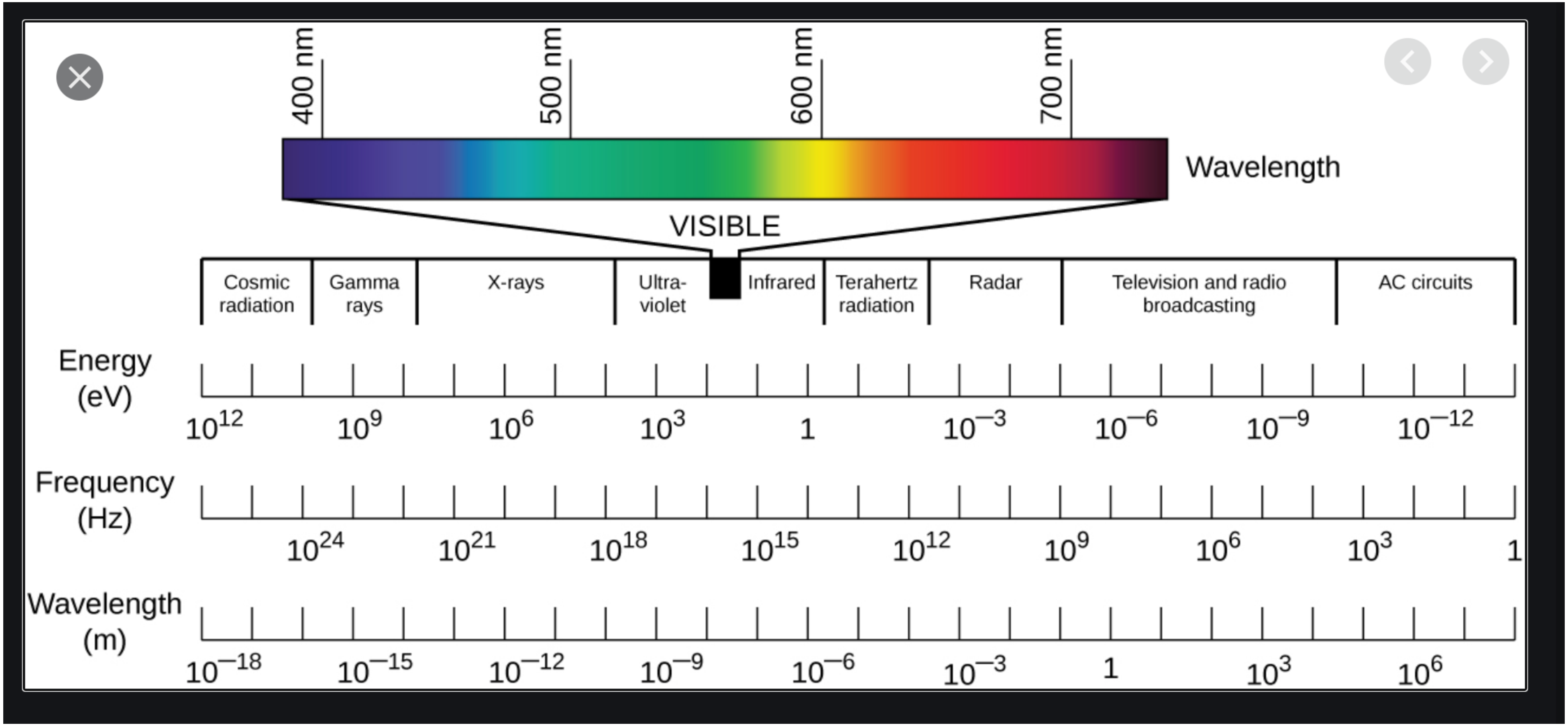
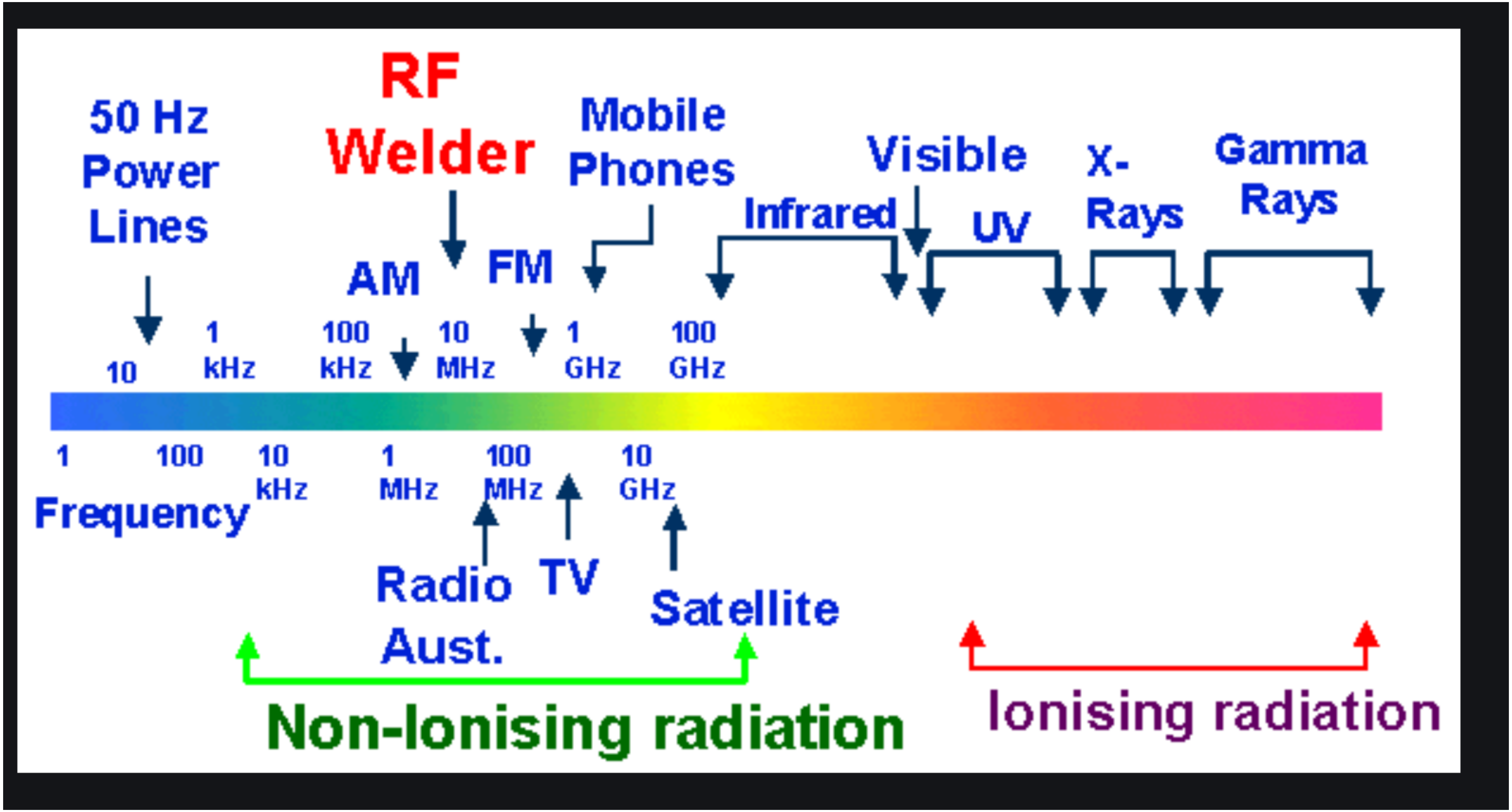
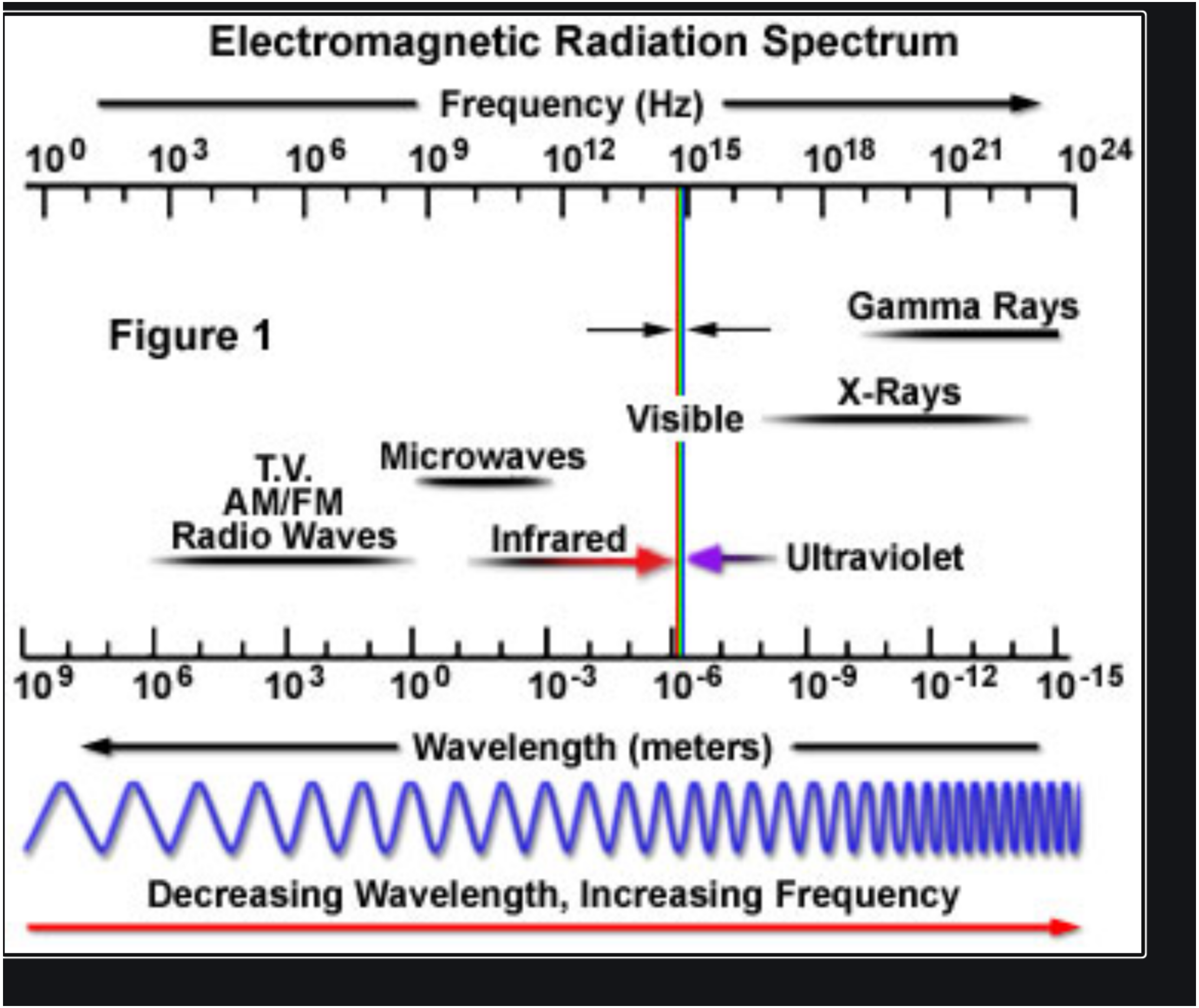

ELECTROMAGNETIC RADIATION SPECTRUM
Size reference
football field
man's height
baseball
paperclip thickness
paper thickness
blood cells
bacteria
viruses
water molecule
atom
atomic nucleus
wavelength λ (m)
1 ft
1 cm
1 mm
1 mil
1 μ
1 nm
1 A
1 pm
10^3 10^2 10^2 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
Biological Effect
Non-ionizing Radiation
Induced Currents
Heating
Ex & Phcm
Ionizing Radiation
Ionization – DNA Damage
electron volt (eV)
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^2 10^3 10^4 10^5 10^6
frequency (Hz)
1 MHz
1 GHz
1 THz
1 PHz
1 EHz
1 ZHz
10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}
Bands
Radio Spectrum
Broadcast and Wireless
Microwave
Terahertz
Infrared
Ultraviolet
X-rays & Gamma Rays
Soft X-ray
Hard X-ray
Sources and Uses of Frequency Bands
electronics
optics
Visible wavelengths (nm)
700 625 575 540 470 440
AM radio
600kHz-1.6MHz
FM radio
88-108 MHz
Mobile Phones
900MHz-2.4GHz
RADAR
1-100 GHz
MRI (1.5T)
63.86 MHz
TV Broadcast
54-700 MHz
Wireless Data
~2.4 GHz
SmartMeter
0.9-2.45 GHz
Microwave Oven
2.4 GHz
Screening
0.2-4.0 THz
"mm wave"
"sub-mm"
Fiber telecom
0.7-1.4 μm
Dental Curing
200-350nm
Visible Light
700-400nm
Remotes
850 nm
Night Vision
10-0.7 μm
Suntan
400-290nm
Medical X-ray
80 kev
Cosmic Gamma Rays
>10Bev
Baggage Screen
160 keV
PET
511 kev
Bone Scan
140 keV

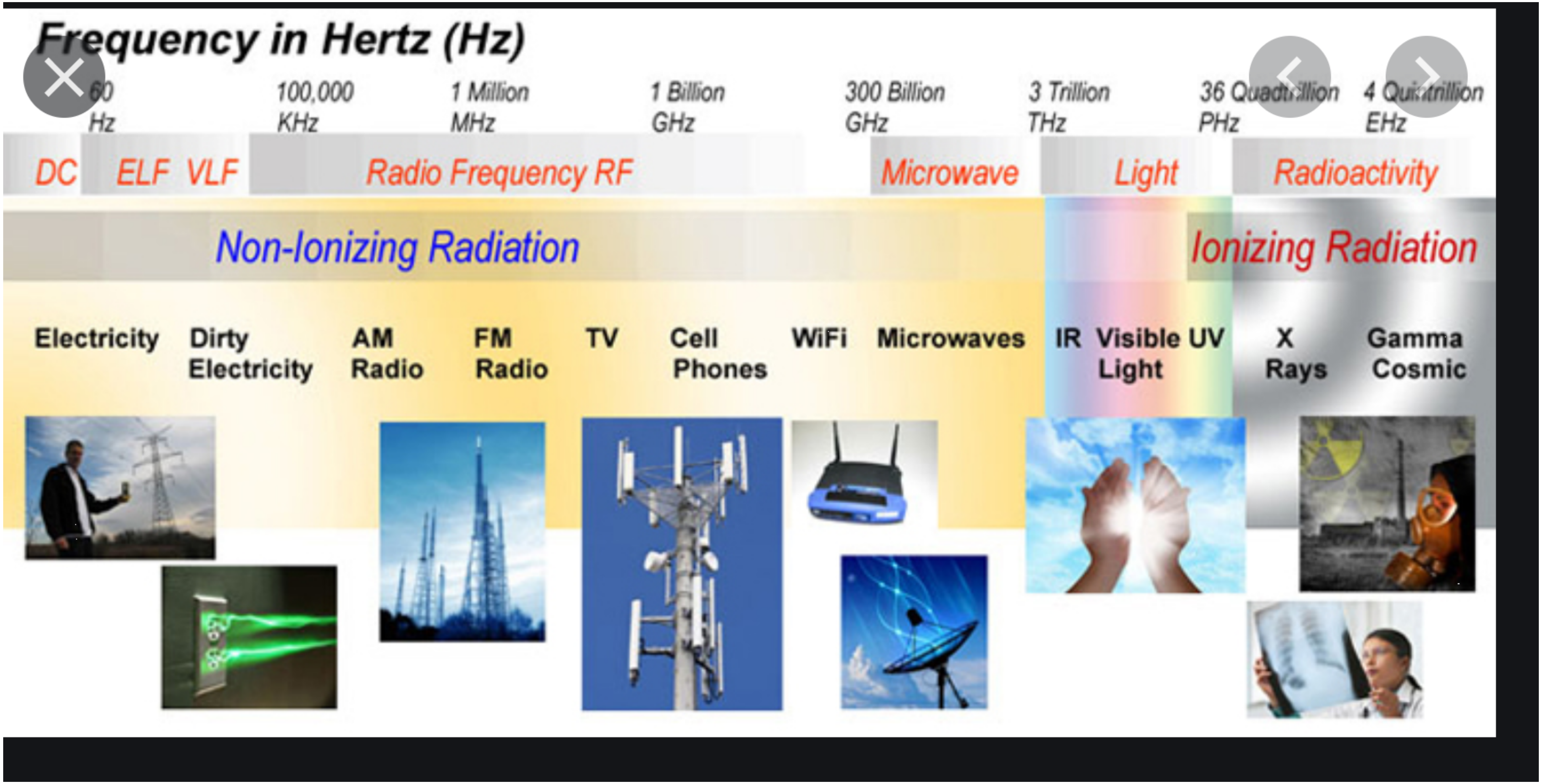


SOUND
RADIO
LIGHT
HARMFUL RADIATION
THE RADIO SPECTRUM
ELF
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
IR
VISIBLE
UV
SOFT X-RAY
X-RAY
SOFT GAMMA-RAY
HARD GAMMA-RAY
GAMMA-RAY
COSMIC-RAY
ISM = Industrial, Scientific and Medical
UWB = Ultra Wide Band
4G CELLULAR
56-100 GHz
VHF = VERY HIGH FREQUENCY
UHF = ULTRA HIGH FREQUENCY
SHF = SUPER HIGH FREQUENCY
EHF = EXTREMELY HIGH FREQUENCY
ISM bands
315-915 MHz
2.4 GHz
ISM band
UWB
3.1-10.6 GHz
30 km
0.3 km
3 m
3 cm
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
AM Broadcast
FM Broadcast
Radar Bands
Sonics
Ultra-sonics
Microwaves
10 kHz
1 MHz
100 MHz
10 GHz
Electromagnetic Spectrum


400 nm
500 nm
600 nm
700 nm
Wavelength
VISIBLE
Cosmic radiation
Gamma rays
X-rays
Ultra-violet
Infrared
Terahertz radiation
Radar
Television and radio broadcasting
AC circuits
Energy (eV)
10^12 10^9 10^6 10^3 1 10^−3 10^−6 10^−9 10^−12
Frequency (Hz)
10^24 10^21 10^18 10^15 10^12 10^9 10^6 10^3 1
Wavelength (m)
10^−18 10^−15 10^−12 10^−9 10^−6 10^−3 1 10^3 10^6


RF
Welder
50 Hz
Power
Lines
Mobile
Phones
Visible
X-
Rays
Gamma
Rays
Infrared
UV
AM
FM
10
1
kHz
100
kHz
10
MHz
1
GHz
100
GHz
1
100
10
kHz
1
MHz
100
MHz
10
GHz
Frequency
Radio
Aust.
TV
Satellite
Non-Ionising radiation
Ionising radiation


Electromagnetic Radiation Spectrum
Frequency (Hz)
10^0 10^3 10^6 10^9 10^12 10^15 10^18 10^21 10^24
Figure 1
Gamma Rays
X-Rays
Visible
Microwaves
T.V.
AM/FM
Radio Waves
Infrared
Ultraviolet
10^9 10^6 10^3 10^0 10^-3 10^-6 10^-9 10^-12 10^-15
Wavelength (meters)
Decreasing Wavelength, Increasing Frequency



Frequency in Hertz (Hz)
60 Hz
100,000 KHz
1 Million MHz
1 Billion GHz
300 Billion GHz
3 Trillion THz
36 Quadtrillion PHz
4 Quintrillion EHz
DC
ELF VLF
Radio Frequency RF
Microwave
Light
Radioactivity
Non-Ionizing Radiation
Ionizing Radiation
Electricity
Dirty Electricity
AM Radio
FM Radio
TV
Cell Phones
WiFi
Microwaves
IR
Visible Light
UV
X Rays
Gamma Cosmic

Name	Wavelength	Frequency (Hz)	Photon Energy (eV)
Gamma ray	Less than 0.01 nm	more than 10 EHz	100 kev - 300+ GeV
X - ray	0.01 - 10 nm	30 EHz - 30 PHz	120 eV - 120 keV
Ultraviolet	10 nm - 400 nm	30 PHz - 790 THz	3 eV - 124 eV
Visible	390 nm - 750 nm	790 THz - 405 THz	1.7 eV - 3.3 eV
Infrared	750 nm - 1 mm	405 THz - 300 GHz	1.24 meV -1.7 eV
Microwave	1 mm - 1 meter	300 GHz - 300 MHz	1.24 μ eV - 1.24 meV
Radio	1 mm - km	300 GHz - 3 Hz	12.4 feV - 1.24 meV

Type of wave	Production	Applications	Issues
Radio	Accelerating charges	Communications Remote controls MRI	Requires control for band use
Microwaves	Accelerating charges and thermal agitation	Communications Ovens Radar Cell phone use	
Infrared	Thermal agitation and electronic transitions	Thermal imaging Heating	Absorbed by atmosphere Greenhouse effect
Visible light	Thermal agitation and electronic transitions	Photosynthesis Human vision	
Ultraviolet	Thermal agitation and electronic transitions	Sterilization Vitamin D production	Ozone depletion Cancer causing
X-rays	Inner electronic transitions and fast collisions	Security Medical diagnosis Cancer therapy	Cancer causing
Gamma rays	Nuclear decay	Nuclear medicine Security Medical diagnosis Cancer therapy	Cancer causing Radiation damage

The relationship $c = f\lambda$ between frequency f and wavelength λ applies to all waves and ensures that greater frequency means smaller wavelength. Figure shows how the various types of electromagnetic waves are categorized according to their wavelengths and frequencies—that is, it shows the electromagnetic spectrum.

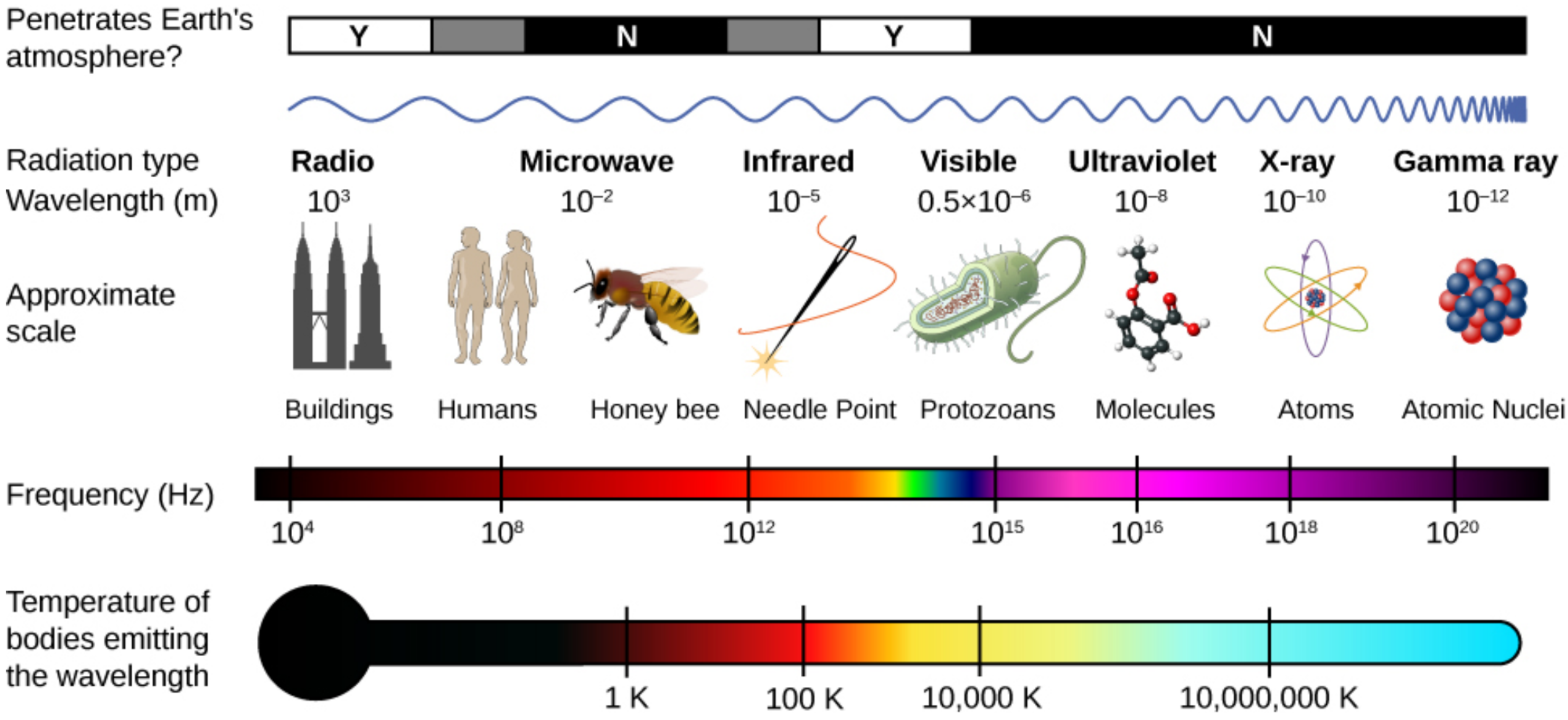


Figure 1 The electromagnetic spectrum, showing the major categories of electromagnetic waves

Radio Waves

The term **radio waves** refers to electromagnetic radiation with wavelengths greater than about 0.1 m. Radio waves are commonly used for audio communications (i.e., for radios), but the term is used for electromagnetic waves in this range regardless of their application. Radio waves typically result from an alternating current in the wires of a broadcast antenna. They cover a very broad wavelength range and are divided into many subranges, including microwaves, electromagnetic waves used for AM and FM radio, cellular telephones, and TV signals.

There is no lowest frequency of radio waves, but ELF waves, or “extremely low frequency” are among the lowest frequencies commonly encountered, from 3 Hz to 3 kHz. The accelerating charge in the ac currents of electrical power lines produce electromagnetic waves in this range. ELF waves are able to penetrate sea water, which strongly absorbs electromagnetic waves of higher frequency, and therefore are useful for submarine communications.

In order to use an electromagnetic wave to transmit information, the amplitude, frequency, or phase of the wave is *modulated*, or varied in a controlled way that encodes the intended information into the wave. In AM radio transmission, the amplitude of the wave is modulated to mimic the vibrations of the sound being conveyed. Fourier’s theorem implies that the modulated AM wave amounts to a superposition of waves covering some narrow frequency range. Each AM station is assigned a specific carrier frequency that, by international agreement, is allowed to vary by $\pm 5\ \mathrm{kHz}$. In FM radio transmission, the frequency of the wave is modulated to carry this information, as illustrated in Figure, and the frequency of each station is allowed to use 100 kHz on each side of its carrier frequency. The electromagnetic wave produces a current in a receiving antenna, and the radio or television processes the signal to produce the sound and any image. The higher the frequency of the radio wave used to carry the data, the greater the detailed variation of the wave that can be carried by modulating it over each time unit, and the more data that can be transmitted per unit of time. The assigned frequencies for AM broadcasting are 540 to 1600 kHz, and for FM are 88 MHz to108 MHz.

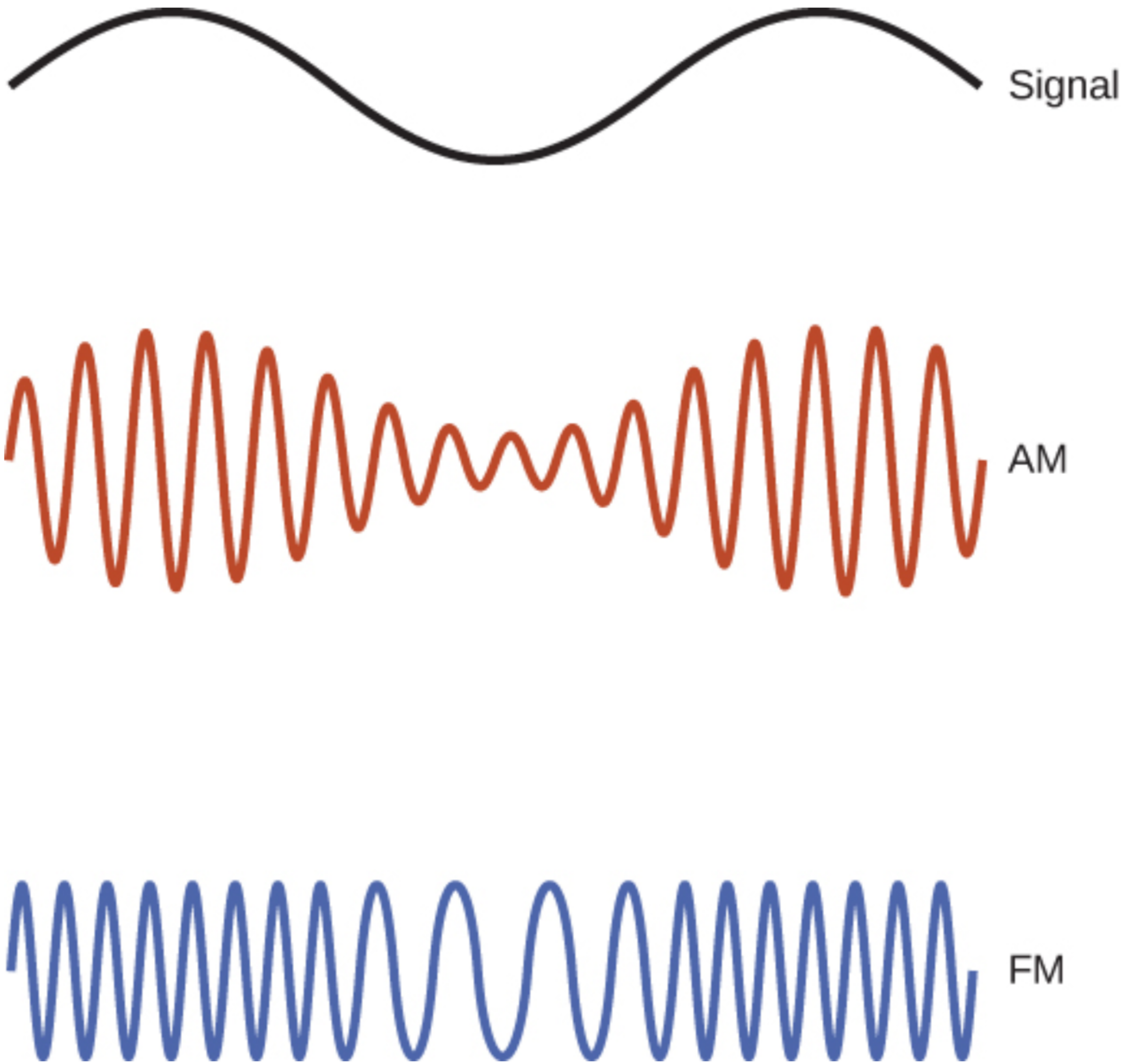


Figure 2. Electromagnetic waves are used to carry communications signals by varying the wave's amplitude (AM), its frequency (FM), or its phase.

Microwaves

Microwaves are the highest-frequency electromagnetic waves that can be produced by currents in macroscopic circuits and devices. Microwave frequencies range from about $10^9 \mathrm{Hz}$ to nearly $10^{12} \mathrm{Hz}$. Their high frequencies correspond to short wavelengths compared with other radio waves—hence the name "microwave." Microwaves also occur naturally as the cosmic background radiation left over from the origin of the universe. Along with other ranges of electromagnetic waves, they are part of the radiation that any object above absolute zero emits and absorbs because of **thermal agitation**, that is, from the thermal motion of its atoms and molecules.

Most satellite-transmitted information is carried on **microwaves**. **Radar** is a common application of microwaves. By detecting and timing microwave echoes, **radar** systems can determine the distance to objects as diverse as clouds, aircraft, or even the surface of Venus.

Microwaves of 2.45 GHz are commonly used in microwave ovens. The electrons in a water molecule tend to remain closer to the oxygen nucleus than the hydrogen nuclei (Figure). This creates two separated centers of equal and opposite charges, giving the molecule a dipole moment (see Electric Field). The oscillating electric field of the microwaves inside the oven exerts a torque that tends to align each molecule first in one direction and then in the other, with the motion of each molecule coupled to others around it. This pumps energy into the continual thermal motion of the water to heat the food. The plate under the food contains no water, and remains relatively unheated.

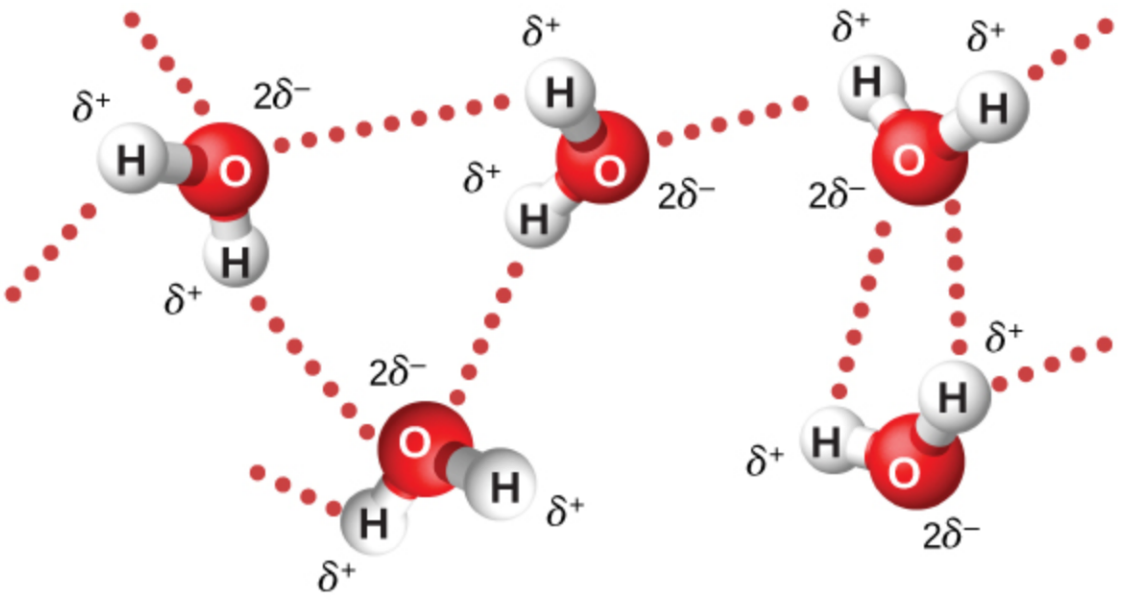


Figure 3. The oscillating electric field in a microwave oven exerts a torque on water molecules because of their dipole moment, and the torque reverses direction 4.90×10^9 times per second. Interactions between the molecules distributes the energy being pumped into them. The δ^+ and δ^- denote the charge distribution on the molecules.

Infrared Radiation

The boundary between the microwave and infrared regions of the electromagnetic spectrum is not well defined (see Figure). **Infrared radiation** is generally produced by thermal motion, and the vibration and rotation of atoms and molecules. Electronic transitions in atoms and molecules can also produce **infrared radiation**. About half of the solar energy arriving at Earth is in the infrared region, with most of the rest in the visible part of the spectrum. About 23% of the solar energy is absorbed in the atmosphere, about 48% is absorbed at Earth’s surface, and about 29% is reflected back into space.[1]

The range of infrared frequencies extends up to the lower limit of visible light, just below red. In fact, infrared means “below red.” Water molecules rotate and vibrate particularly well at infrared frequencies. Reconnaissance satellites can detect buildings, vehicles, and even individual humans by their infrared emissions, whose power radiation is proportional to the fourth power of the absolute temperature. More mundanely, we use infrared lamps, including those called *quartz heaters*, to preferentially warm us because we absorb infrared better than our surroundings.

The familiar handheld “remotes” for changing channels and settings on television sets often transmit their signal by modulating an infrared beam. If you try to use a TV remote without the infrared emitter being in direct line of sight with the infrared detector, you may find the television not responding. Some remotes use Bluetooth instead and reduce this annoyance.

Visible Light

Visible light is the narrow segment of the electromagnetic spectrum between about 400 nm and about 750 nm to which the normal human eye responds. Visible light is produced by vibrations and rotations of atoms and molecules, as well as by electronic transitions within atoms and molecules. The receivers or detectors of light largely utilize electronic transitions.

Red light has the lowest frequencies and longest wavelengths, whereas violet has the highest frequencies and shortest wavelengths (Figure). Blackbody radiation from the Sun peaks in the visible part of the spectrum but is more intense in the red than in the violet, making the sun yellowish in appearance.

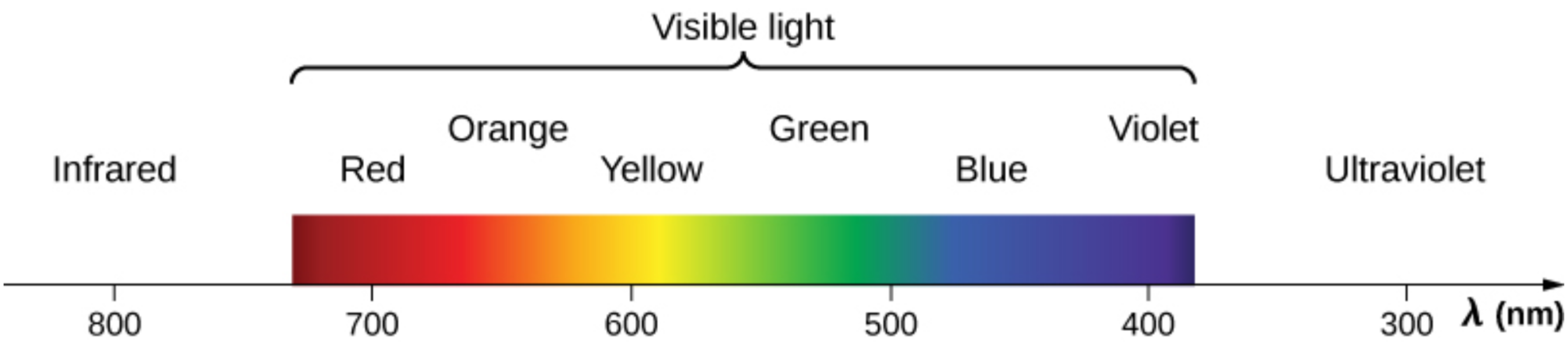


Figure 4. A small part of the electromagnetic spectrum that includes its visible components. The divisions between infrared, visible, and ultraviolet are not perfectly distinct, nor are those between the seven rainbow colors.

Living things—plants and animals—have evolved to utilize and respond to parts of the electromagnetic spectrum in which they are embedded. We enjoy the beauty of nature through visible light. Plants are more selective. Photosynthesis uses parts of the visible spectrum to make sugars.

Ultraviolet Radiation

Ultraviolet means “above violet.” The electromagnetic frequencies of **ultraviolet radiation (UV)** extend upward from violet, the highest-frequency visible light. The highest-frequency ultraviolet overlaps with the lowest-frequency X-rays. The wavelengths of ultraviolet extend from 400 nm down to about 10 nm at its highest frequencies. Ultraviolet is produced by atomic and molecular motions and electronic transitions.

UV radiation from the Sun is broadly subdivided into three wavelength ranges: UV-A (320–400 nm) is the lowest frequency, then UV-B (290–320 nm) and UV-C (220–290 nm). Most UV-B and all UV-C are absorbed by ozone (O_3) molecules in the upper atmosphere. Consequently, 99% of the solar UV radiation reaching Earth’s surface is UV-A.

Sunburn is caused by large exposures to UV-B and UV-C, and repeated exposure can increase the likelihood of skin cancer. The tanning response is a defense mechanism in which the body produces pigments in inert skin layers to reduce exposure of the living cells below.

As examined in a later chapter, the shorter the wavelength of light, the greater the energy change of an atom or molecule that absorbs the light in an electronic transition. This makes short-wavelength ultraviolet light damaging to living cells. It also explains why ultraviolet radiation is better able than visible light to cause some materials to glow, or *fluoresce*.

Besides the adverse effects of ultraviolet radiation, there are also benefits of exposure in nature and uses in technology. Vitamin D production in the skin results from exposure to UV-B radiation, generally from sunlight. Several studies suggest vitamin D deficiency is associated with the development of a range of cancers (prostate, breast, colon), as well as osteoporosis. Low-intensity ultraviolet has applications such as providing the energy to cause certain dyes to fluoresce and emit visible light, for example, in printed money to display hidden watermarks as counterfeit protection.

X-Rays

X-rays have wavelengths from about $10^{-8}\mathrm{m}$ to $10^{-12}\mathrm{m}$. They have shorter wavelengths, and higher frequencies, than ultraviolet, so that the energy they transfer at an atomic level is greater. As a result, X-rays have adverse effects on living cells similar to those of ultraviolet radiation, but they are more penetrating. Cancer and genetic defects can be induced by X-rays. Because of their effect on rapidly dividing cells, X-rays can also be used to treat and even cure cancer.

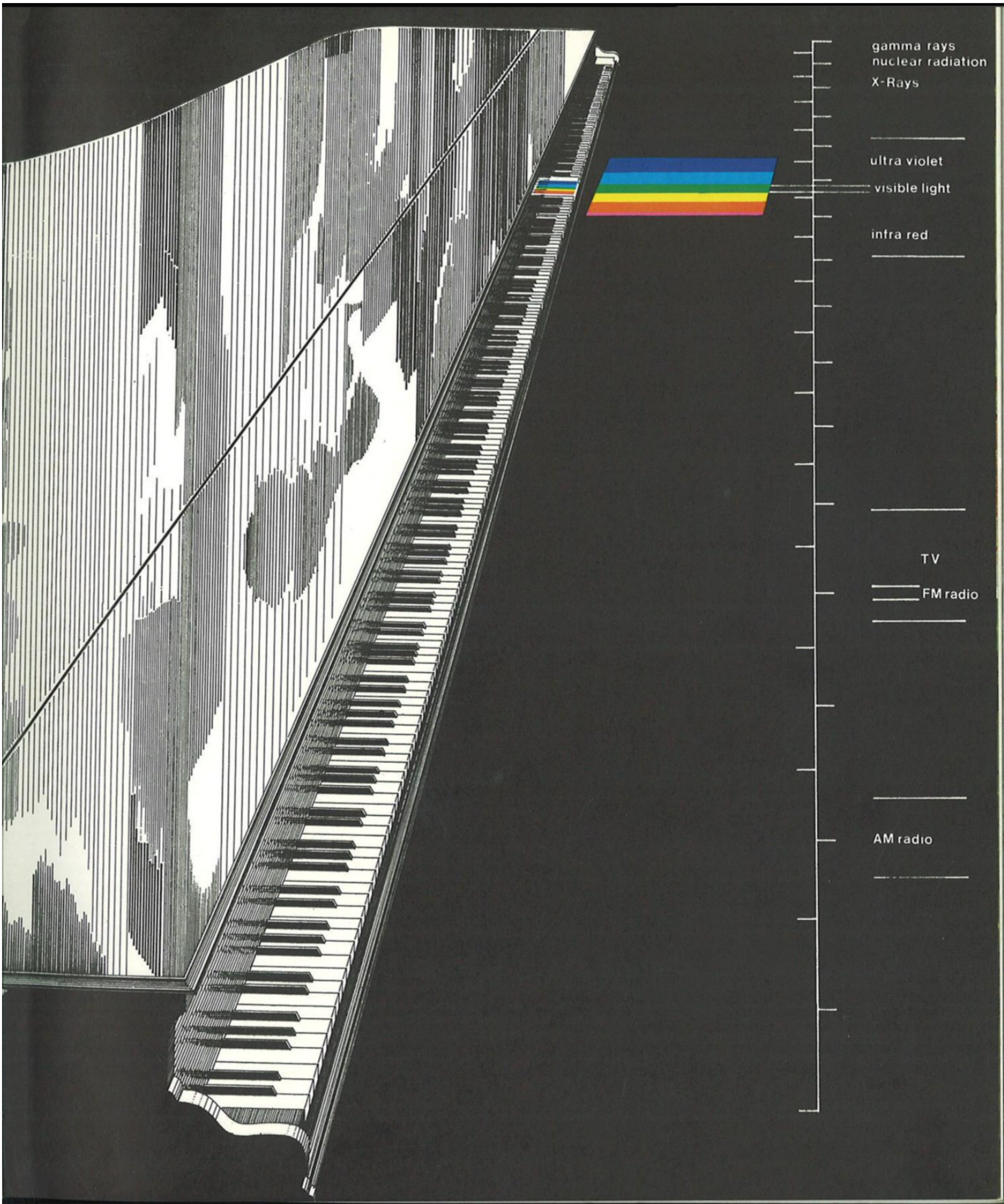
The widest use of X-rays is for imaging objects that are opaque to visible light, such as the human body or aircraft parts. In humans, the risk of cell damage is weighed carefully against the benefit of the diagnostic information obtained.

Gamma Rays

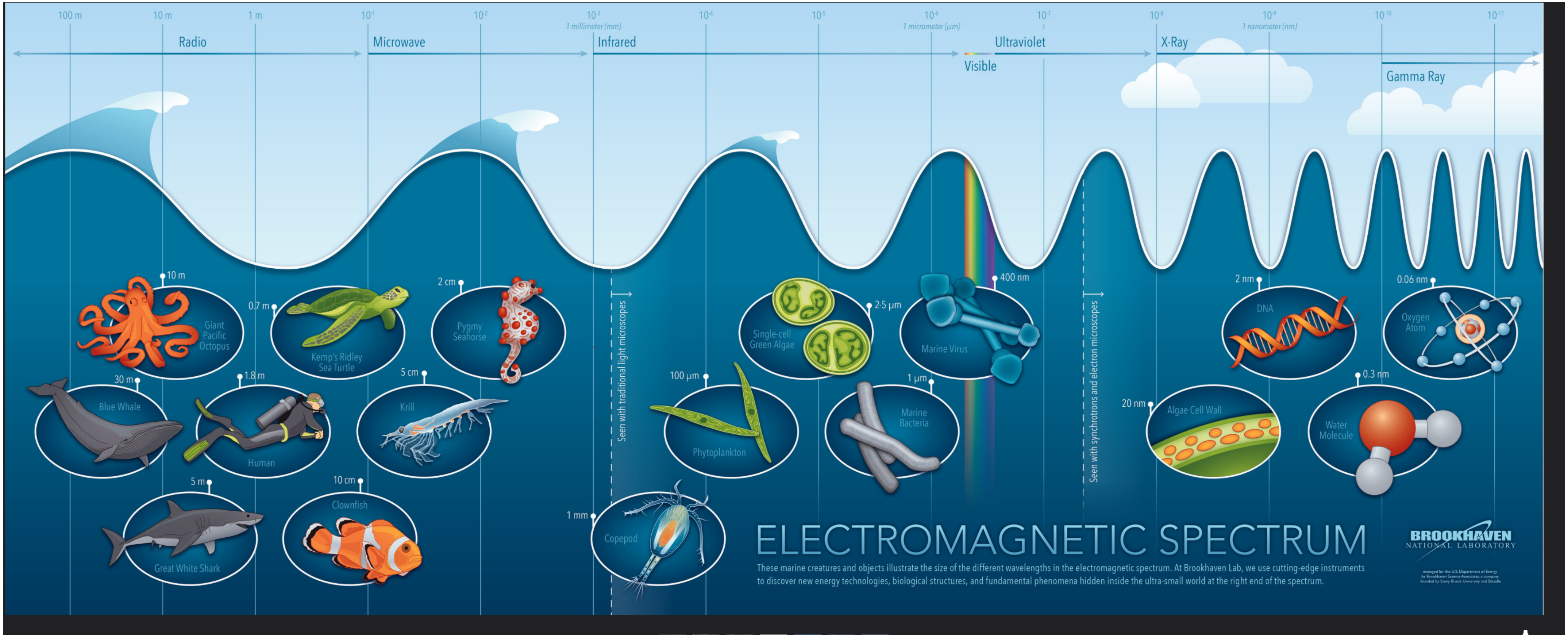
Soon after nuclear radioactivity was first detected in 1896, it was found that at least three distinct types of radiation were being emitted, and these were designated as alpha, beta, and gamma rays. The most penetrating nuclear radiation, the **gamma ray (γ ray)**, was later found to be an extremely high-frequency electromagnetic wave.

The lower end of the γ- ray frequency range overlaps the upper end of the X-ray range. Gamma rays have characteristics identical to X-rays of the same frequency—they differ only in source. The name “gamma rays” is generally used for electromagnetic radiation emitted by a nucleus, while X-rays are generally produced by bombarding a target with energetic electrons in an X-ray tube. At higher frequencies, γ rays are more penetrating and more damaging to living tissue. They have many of the same uses as X-rays, including cancer therapy. Gamma radiation from radioactive materials is used in nuclear medicine.

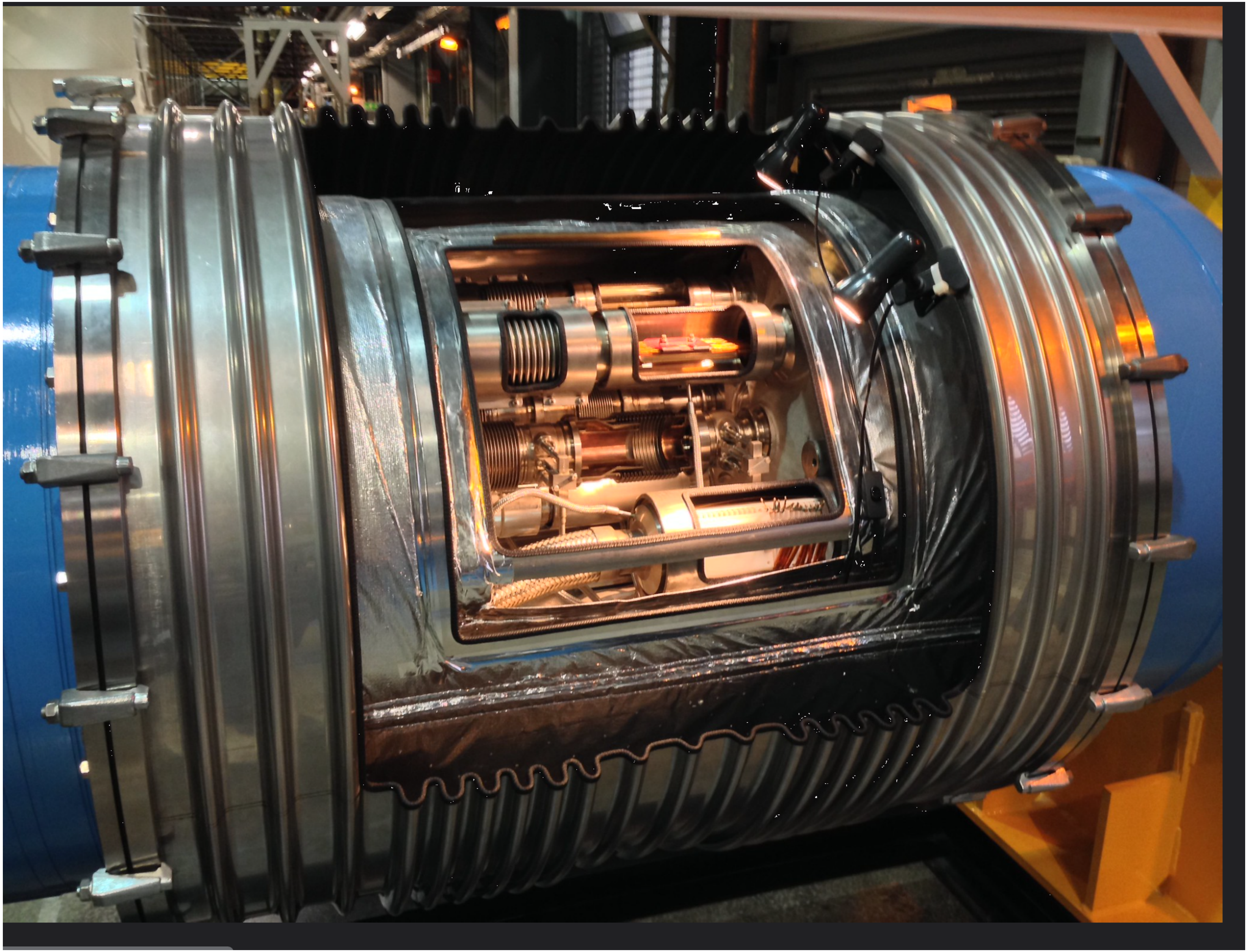
Displacement current	$I_{\mathrm{d}} = \varepsilon_0 \frac{d\Phi_{\mathrm{E}}}{dt}$
Gauss's law	$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{Q_{\mathrm{in}}}{\varepsilon_0}$
Gauss's law for magnetism	$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$
Faraday's law	$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}} = -\frac{d\Phi_{\mathrm{m}}}{dt}$
Ampère-Maxwell law	$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} = \mu_0 I + \varepsilon_0 \mu_0 \frac{d\Phi_{\mathrm{E}}}{dt}$
Wave equation for plane EM wave	$\frac{\partial^2 E_y}{\partial x^2} = \varepsilon_0 \mu_0 \frac{\partial^2 E_y}{\partial t^2}$
Speed of EM waves	$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$
Ratio of *E* field to *B* field in electromagnetic wave	$c = \frac{E}{B}$
Energy flux (Poynting) vector	$\vec{\mathbf{S}} = \frac{1}{\mu_0} \vec{\mathbf{E}} \times \vec{\mathbf{B}}$
Average intensity of an electromagnetic wave	$I = S_{\mathrm{avg}} = \frac{c\varepsilon_0 E_0^2}{2} = \frac{cB_0^2}{2\mu_0} = \frac{E_0 B_0}{2\mu_0}$
Radiation pressure	$p = \begin{cases} I/c & \text{Perfect absorber} \\ 2I/c & \text{Perfect reflector} \end{cases}$



s of electro-magnetic radiation



100 m
10 m
1 m
10^{-1}
10^{-2}
10^{-3}
1 millimeter (mm)
10^{-4}
10^{-5}
10^{-6}
1 micrometer (µm)
10^{-7}
10^{-8}
10^{-9}
1 nanometer (nm)
10^{-10}
10^{-11}
Radio
Microwave
Infrared
Visible
Ultraviolet
X-Ray
Gamma Ray
10 m
Giant Pacific Octopus
0.7 m
Kemp's Ridley Sea Turtle
2 cm
Pygmy Seahorse
30 m
Blue Whale
1.8 m
Human
5 cm
Krill
5 m
Great White Shark
10 cm
Clownfish
Seen with traditional light microscopes
1 mm
Copepod
100 µm
Phytoplankton
2-5 µm
Single-cell Green Algae
400 nm
Marine Virus
1 µm
Marine Bacteria
Seen with synchrotrons and electron microscopes
2 nm
DNA
20 nm
Algae Cell Wall
0.06 nm
Oxygen Atom
0.3 nm
Water Molecule
ELECTROMAGNETIC SPECTRUM
These marine creatures and objects illustrate the size of the different wavelengths in the electromagnetic spectrum. At Brookhaven Lab, we use cutting-edge instruments to discover new energy technologies, biological structures, and fundamental phenomena hidden inside the ultra-small world at the right end of the spectrum.
BROOKHAVEN NATIONAL LABORATORY
managed for the U.S. Department of Energy by Brookhaven Science Associates, a company founded by Stony Brook University and Battelle



Region	Sub-region	Frequency (Hz)	Wavelength	Energy (eV)
Radio wave		$< 10^9$	> 0.3m	$< 7*10^{-7}$
Microwave		10^9- $0.003*10^{14}$	0.3m - 1mm	$7*10^{-7}$-0.0012
	Far infrared	$0.003*10^{14}$-$0.2*10^{14}$	1mm - 20µm	0.0012-0.08
	Long-wave infrared	$0.20*10^{14}$-$0.37*10^{14}$	20µm - 5µm	0.08-0.15
Infrared	*Mid-wave infrared*	$0.37*10^{14}$-10^{14}	5µm - 3µm	0.15-0.41
	Shortwave infrared	10^{14}-$2.14*10^{14}$	3µm - 1.1µm	0.41-0.88
	Near infrared	$2.14*10^{14}$-$4*10^{14}$	1.1µm -0.78µm	0.88-1.6
	Red	$3.8*10^{14}$-$4.8*10^{14}$	789nm-625nm	1.6-1.9
	Orange	$4.8*10^{14}$-$5*10^{14}$	625nm-600nm	1.9-2.1
Visible	*Yellow*	$5*10^{14}$-$5.2*10^{14}$	600nm-577nm	2.1-2.2
	Green	$5.2*10^{14}$-$6.1*10^{14}$	577nm-491nm	2.2-2.4
	Blue	$6.1*10^{14}$-$6.59*10^{14}$	491nm-455nm	2.4-2.8
	Violet	$6.59*10^{14}$-$8*10^{14}$	455nm-390nm	2.8-3.1
Ultra Violet		$8*10^{14}$-$2.4*10^{16}$	390nm-8.82nm	3.1-20
X ray		$2.4*10^{16}$-$5*10^{19}$	8.82nm-6pm	20-$3*10^4$
Gamma ray		$> 5*10^{19}$	< 6pm	$> 3*10^4$

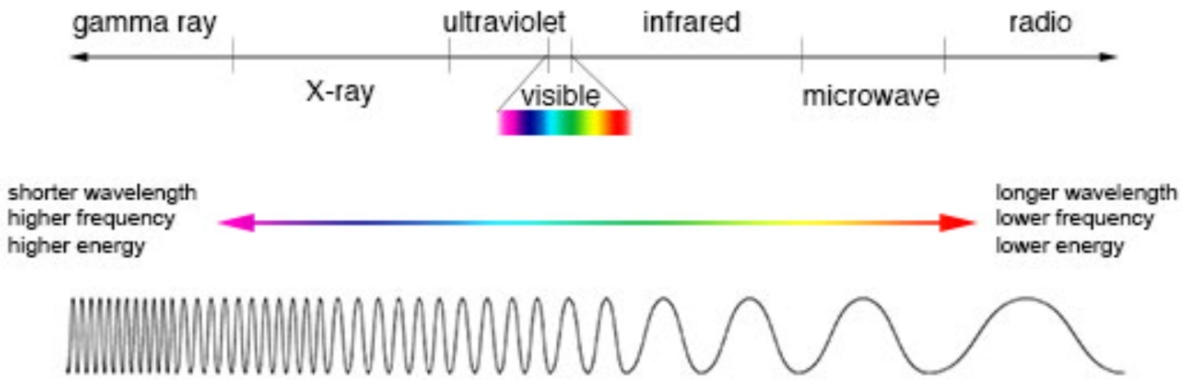
f	λ	Band	Description
30–300 Hz	10^4–10^3 km	ELF	Extremely low frequency
300–3000 Hz	10^3–10^2 km	VF	Voice frequency
3–30 kHz	100–10 km	VLF	Very low frequency
30–300 kHz	10–1 km	LF	Low frequency
0.3–3 MHz	1–0.1 km	MF	Medium frequency
3–30 MHz	100–10 m	HF	High frequency
30–300 MHz	10–1 m	VHF	Very high frequency
300–3000 MHz	100–10 cm	UHF	Ultra-high frequency
3–30 GHz	10–1 cm	SHF	Superhigh frequency
30–300 GHz	10–1 mm	EHF	Extremely high frequency (millimeter waves)

Are radio waves completely different physical objects than gamma-rays? They are produced in different processes and are detected in different ways, but they are not fundamentally different. Radio waves, gamma-rays, visible light, and all the other parts of the electromagnetic spectrum are electromagnetic radiation.

Electromagnetic radiation can be described in terms of a stream of mass-less particles, called photons, each traveling in a wave-like pattern at the speed of light. Each photon contains a certain amount of energy. The different types of radiation are defined by the the amount of energy found in the photons. Radio waves have photons with low energies, microwave photons have a little more energy than radio waves, infrared photons have still more, then visible, ultraviolet, X-rays, and, the most energetic of all, gamma-rays.

Measuring electromagnetic radiation

Electromagnetic radiation can be expressed in terms of energy, wavelength, or frequency. Frequency is measured in cycles per second, or Hertz. Wavelength is measured in meters. Energy is measured in electron volts. Each of these three quantities for describing EM radiation are related to each other in a precise mathematical way. But why have three ways of describing things, each with a different set of physical units?

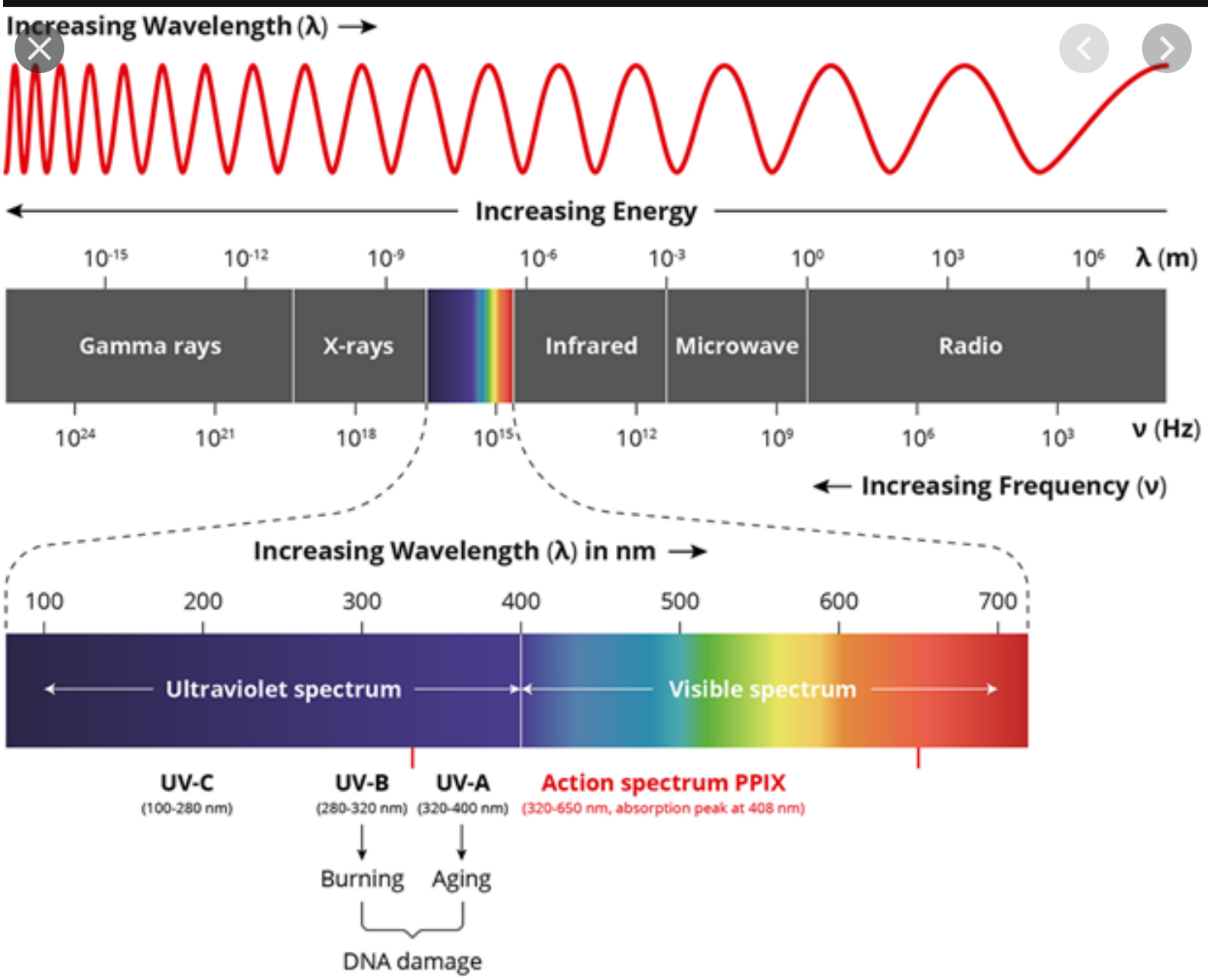


Comparison of wavelength, frequency and energy for the electromagnetic spectrum.
(Credit: NASA's Imagine the Universe)

The short answer is that scientists don't like to use numbers any bigger or smaller than they have to. It is much easier to say or write "two kilometers" than "two thousand meters." Generally, scientists use whatever units are easiest for the type of EM radiation they work with.

Astronomers who study radio waves tend to use wavelengths or frequencies. Most of the radio part of the EM spectrum falls in the range from about 1 cm to 1 km, which is 30 gigahertz (GHz) to 300 kilohertz (kHz) in frequencies. The radio is a very broad part of the EM spectrum.

Infrared and optical astronomers generally use wavelength. Infrared astronomers use microns (millionths of a meter) for wavelengths, so their part of the EM spectrum falls in the range of 1 to 100 microns. Optical astronomers use both angstroms (0.00000001 cm, or 10^{-8} cm) and nanometers (0.0000001 cm, or 10^{-7} cm). Using nanometers, violet, blue, green, yellow, orange, and red light have wavelengths between 400 and 700 nanometers. (This range is just a tiny part of the entire EM spectrum, so the light our eyes can see is just a little fraction of all the EM radiation around us.)



Increasing Wavelength (λ) →
Increasing Energy
10-15
10-12
10-9
10-6
10-3
100
103
106
λ (m)
Gamma rays
X-rays
Infrared
Microwave
Radio
1024
1021
1018
1015
1012
109
106
103
ν (Hz)
← Increasing Frequency (ν)
Increasing Wavelength (λ) in nm →
100
200
300
400
500
600
700
Ultraviolet spectrum
Visible spectrum
UV-C
(100-280 nm)
UV-B
(280-320 nm)
UV-A
(320-400 nm)
Action spectrum PPIX
(320-650 nm, absorption peak at 408 nm)
Burning
Aging
DNA damage

The Electromagnetic Spectrum

The electromagnetic spectrum contains different types of transverse waves. All of these waves can undergo interference, be reflected, refracted, diffracted and polarised, and travel at the speed of light, 2.998×10^8 m/s, in a vacuum.

Type	Radio Waves	Microwaves	Infrared (IR)	Optical (visible) Light	Ultraviolet (UV)	X-rays	Gamma Rays
Wavelength (m)	$>1 \times 10^{-1}$	$1 \times 10^{-1} - 1 \times 10^{-3}$	$1 \times 10^{-3} - 7 \times 10^{-7}$	$7 \times 10^{-7} - 4 \times 10^{-7}$	$4 \times 10^{-7} - 1 \times 10^{-8}$	$1 \times 10^{-8} - 1 \times 10^{-13}$	$<10^{-11}$
Longer Wavelength							Shorter Wavelength
Lower Frequency							Higher Frequency
Frequency (Hz)	$<3 \times 10^{9}$	$3 \times 10^{9} - 3 \times 10^{11}$	$3 \times 10^{11} - 4 \times 10^{14}$	$4 \times 10^{14} - 8 \times 10^{14}$	$8 \times 10^{14} - 3 \times 10^{17}$	$3 \times 10^{17} - 3 \times 10^{19}$	$>3 \times 10^{17}$
Energy (J)	$<2 \times 10^{-24}$	$2 \times 10^{-24} - 2 \times 10^{-22}$	$2 \times 10^{-22} - 3 \times 10^{-19}$	$3 \times 10^{-19} - 5 \times 10^{-19}$	$5 \times 10^{-19} - 2 \times 10^{-17}$	$2 \times 10^{-17} - 2 \times 10^{-14}$	$>2 \times 10^{-14}$
How Are They Made?	By oscillating electrons in aerials	Directly produced by electron tube oscillators	By oscillating molecules in hot objects, such as LEDs, flames and stars	Emitted by the sun and other very hot objects, such as light bulbs and laser pointers	Emitted by the sun and other extremely hot objects, such as sparks and UV lamps	By firing electrons at a metal target	Emitted during radioactive decay
Applications	Television, radio, communications	Radar, cooking, satellite communications, mobile phones	Night vision, heat used in toasters and grills, remote controls, thermal imaging	Seeing, communications, optical fibres, DVD players, laser printers	Sunbeds, invisible security marking, sterilisation	X-ray photography, CT scanning, airport security, cancer treatment	Irradiation of food, security, cancer treatment, sterilisation
Dangers	Not thought to be hazardous	Heats water within the body, can damage or kill cells	Felt as heat, can cause skin damage and burns	Can damage the eyes	Can cause sunburn, damages eyes, causes cancer	Damages eyes and cells, causes cancer	Damages eyes and cells, causes cancer
How Are They Detected?	Resonance in electronic circuits using an aerial	Resonance in electronic circuits, heating effect on water	Thermometer, thermopile, heating effect on skin	Photographic film, the eye, photodetectors	Photographic film, sunburn, photodetectors	Photographic film, fluorescence	Photographic film, Geiger-Müller tube

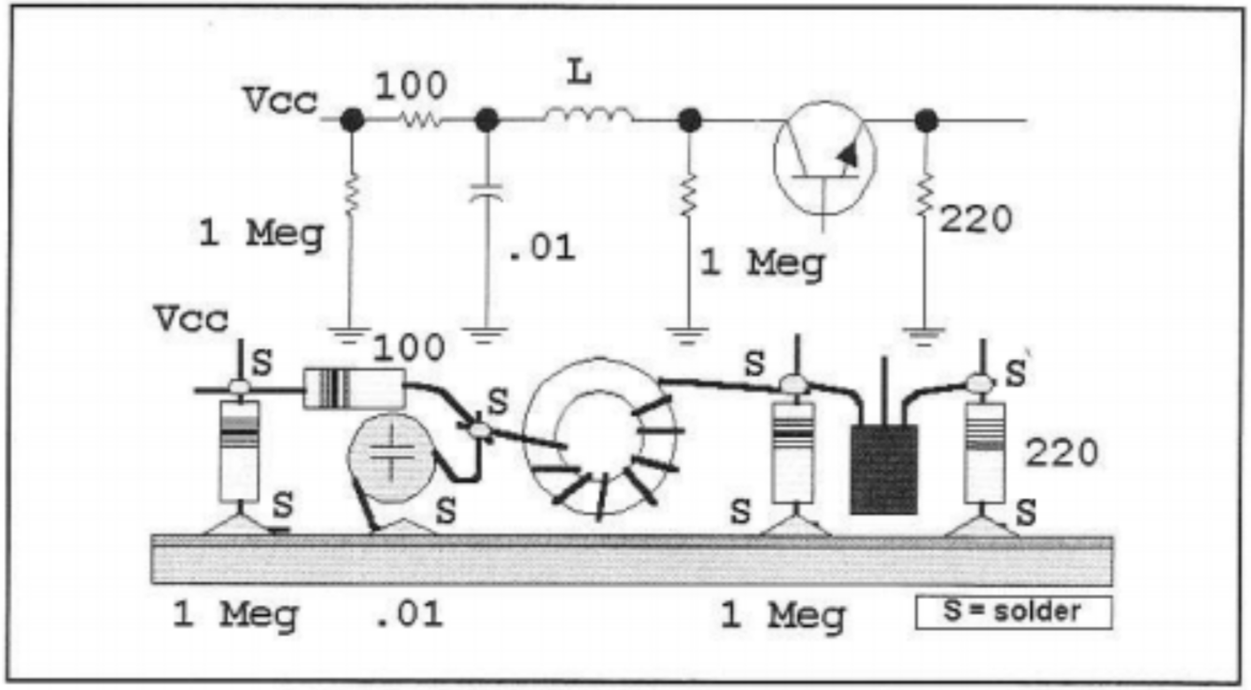


Fig 1.1—A partial circuit illustrating "ugly" construction.

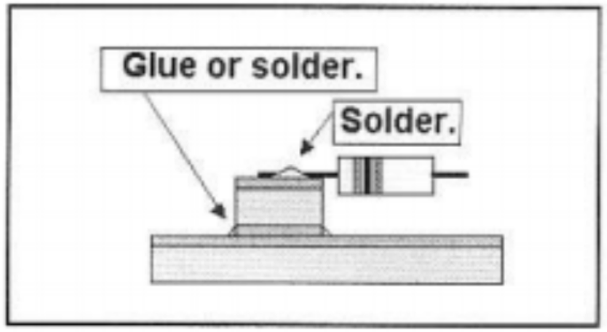


Fig 1.2—An example of "Manhattan" breadboarding.

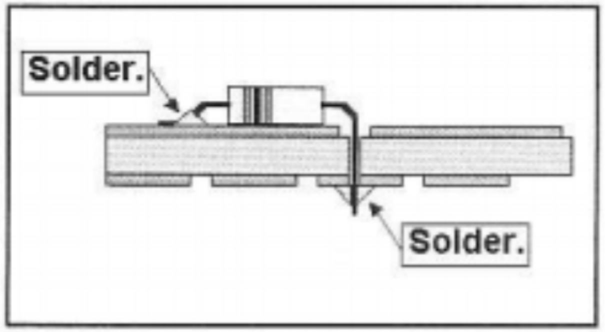
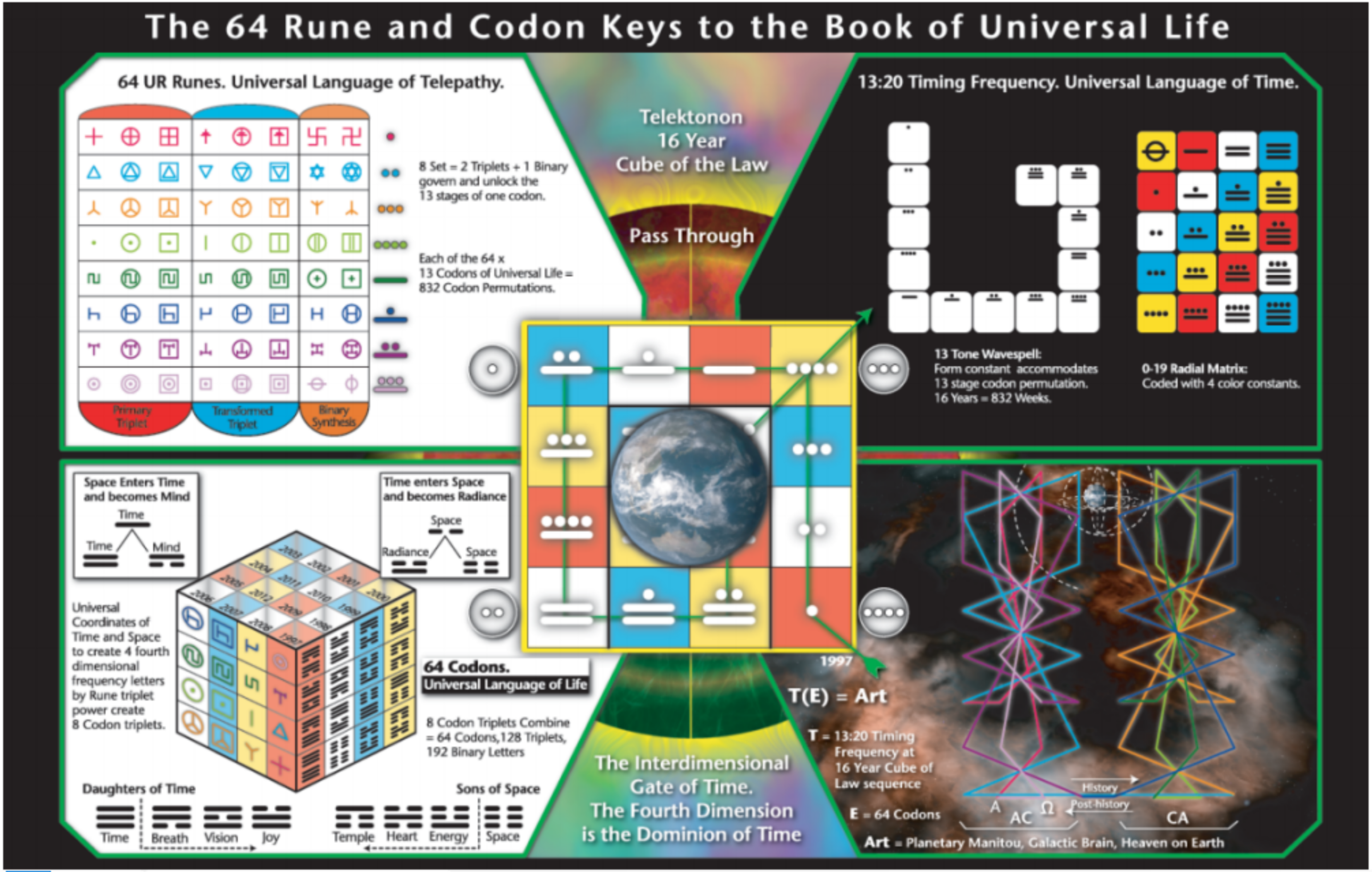


Fig 1.3—A "quasi-circuit board" scheme for breadboarding. The installed resistor here is soldered to ground and to a pad that connects to the rest of the circuitry.

Reactance is little consequence for work up through 150 MHz or so. High R means that resistance is high with respect to the reactance of the inductance. We sometimes use R values as low as 10kΩ. It is often surprising just how few standoff resistors are needed in an ugly breadboard.

The greatest virtue of the ugly method is low inductance grounding. Any construction scheme that preserves this grounding integrity will work as well. Picking a method is a choice that the builder has, a place where he or she can develop the method to be especially useful for slightly massive components such as floating, non-grounded, trimmer capacitors. The specific glue type has little impact on circuit performance. Variations of this method have been called "Manhattan Construction," and can be mixed with other breadboarding schemes. The reader can find numerous examples on the Web on sites dealing with QRP experiments, as well as in **Fig 1.2**.

The proponents of Manhattan Construction often use small round pads that are when the board is not etched in a circuit-specific pattern. One method called


The 64 Rune and Codon Keys to the Book of Universal Life
64 UR Runes. Universal Language of Telepathy.
8 Set = 2 Triplets + 1 Binary govern and unlock the 13 stages of one codon.
Each of the 64 x 13 Codons of Universal Life = 832 Codon Permutations.
Primary Triplet
Transformed Triplet
Binary Synthesis
Telektonon
16 Year
Cube of the Law
Pass Through
13:20 Timing Frequency. Universal Language of Time.
13 Tone Wavespell:
Form constant accommodates 13 stage codon permutation.
16 Years = 832 Weeks.
0-19 Radial Matrix:
Coded with 4 color constants.
Space Enters Time and becomes Mind
Time
Time
Mind
Time enters Space and becomes Radiance
Space
Radiance
Space
Universal Coordinates of Time and Space to create 4 fourth dimensional frequency letters by Rune triplet power create 8 Codon triplets.
64 Codons.
Universal Language of Life
8 Codon Triplets Combine = 64 Codons, 128 Triplets, 192 Binary Letters
Daughters of Time
Time
Breath
Vision
Joy
Sons of Space
Temple
Heart
Energy
Space
1997
The Interdimensional Gate of Time.
The Fourth Dimension is the Dominion of Time
T(E) = Art
T = 13:20 Timing Frequency at 16 Year Cube of Law sequence
E = 64 Codons
History
Post-history
A
AC
Ω
CA
Art = Planetary Manitou, Galactic Brain, Heaven on Earth

180.15%

[illegible] FLAG OF THIS VESSEL

FOR THE **CLAIMANT'S-KNOWLEDGE** OF THIS **LIVE-LIFE** IS WITH THIS **CLAIM BY THIS CLAIMANT.**

~1 FOR THIS **CLAIMANT'S-KNOWLEDGE** OF THIS **LIVE-LIFE** IS WITH THIS CLAIM OF THE

1. **LIVEBIRTH-NAME:** Klaus-Bärbel :Mustermann__________________, ON THIS
2. DATE-~_21___ DAY WITHIN THE MONTH-~_Dezember_, IN THE YEAR-~ 1968 BY THESE **WITNESSES AND THIS CLAIMANT.**

~2 FOR THIS **CLAIMANT'S-KNOWLEDGE** OF THIS **LIVE-LIFEBIRTH** IS WITH THE

3. LOCATION IN THE CITY-~___Hannover____ TERRITORY-~___Preussen_________
4. BY THE PARENTS: FATHER:___Bernhard Mustermann________,
5. MOTHER:___Edith Mustermann______________.

~3 FOR THESE WITNESSES OF THIS **LIVE-LIFEBIRTH** ARE, ON THIS DATE-~_30___ DAY

6. WITHIN THE MONTH-~_August______, IN THE YEAR-~ 2017 WITH THE CLAIM OF
1. THE CLAIM OF THE **LIVE-LIFE-DOCUMENT:** Klaus-Bärbel :Mustermann___________.

Witness 1: Christian :Müller________________________.

Witness 2: Micky :Mouse____________________________.

Witness 3: Wolfgang-Gerhard-Günther :Ebel____________.

~4 FOR THIS **PICTURE, FINGERPRINT-SEAL AND DNA-SAMPLE** OF THIS CLAIMANT ARE WITH THESE CLAIMS OF THIS **FACTUAL-LIVE-LIFEBIRTH:**

: PICTURE :   : FINGERPRINT :   : DNA-BLOOD/SALIVA :

:AUTOGRAPH-CLAIMANT-LIFEBIRTH-:COPYRIGHT/COPYCLAIM : :Klaus-Bärbel :Mustermann___________________:

:AUTOGRAPH-WITNESS-COPYRIGHT/COPYCLAIM: :Christian :Müller____________________:

:AUTOGRAPH-WITNESS-COPYRIGHT/COPYCLAIM: :Micky :Mouse____________________:

:AUTOGRAPH-WITNESS-COPYRIGHT/COPYCLAIM: :Wolfgang-Gerhard-Günther :Ebel____________:

RE 347 000 853 US Amun

:Title~4:U.S.C.-Chap.~1-Sec.~3: Copyclaim~2018

FOR THE CLAIM OF THE LIVE-LIFE IS WITH THE KNOWLEDGE OF THIS CLAIMANT.

~1 FOR THIS CLAIMANT'S-KNOWLEDGE OF THESE FACTS IS WITH THE CLAIM OF THIS LIVE-LIFEBIRTH/NATIVITY: Amun Sobek Ra Eil [YOUR-NAME] ____________ ON THIS BIRTHDATE OF THE DAY ~14th__ IN THE ~MONTH OF THE ~ July IN THE ~YEAR OF THE ~1950 ____________ WITH THE TIME OF THE : 8 : 49 :A.M/P.M.

~2 FOR THESE WITNESS'S-KNOWLEDGE OF THIS LIVE-LIFE ARE WITH THESE CLAIMS OF THIS LIVE-LIFEBIRTH/NATIVITY IN THE CITY OF THE St. Louis IN THE STATE OF THE Missouri IN OUR WORLD WITH THESE PARENT-PARTIES: MOTHER: Corvina Jenkins AND FATHER: Odell Jenkins BY THEIR MARRIAGE.

~3 FOR THESE WITNESSES OF THIS LIVE-LIFE-CLAIMS ARE WITH THE CLAIM OF THIS KNOWLEDGE OF THIS LIVE-LIFEBIRTH WITH THE AUTHORIZATION OF THESE (3)THREE-AUTOGRAPHS OF THESE WITNESSES:

:Heru-Montu Ra Eil **[WITNESS-ONE]** Heru-Montu Ra Eil ©TM,

Ankhta Mut Ra Eil **[WITNESS-TWO]** Ankhta Mut Ra Eil,

Amun Sobek Ra Eil **[YOU]** Amun Sobek Ra Eil.

~4 FOR THE WITNESSE'S-KNOWLEDGE OF THESE FACTS WITH THESE CLAIMS OF THIS LIVE-LIFEBIRTH WITH THIS CORRECT-SENTENCE=STRUCTURE-COMMUNICATION-PARSE=SYNTAX=GRAMMAR OF A LINGQUISTIC-COMMUNICATIONS-CLAIM WITH THIS LIVE-LIFE-PARTY.

:PICTURE

:FINGER PRINT

:BLOOD OR SALIVA

:WITNESS/ Ankhta Mut Ra Eil **:AUTOGRAPH/:COPYCLAIM ~2018**

:WITNESS/ Heru-Montu Ra Eil **:AUTOGRAPH/:COPYCLAIM ~2018**

[YOUR AUTOGRAPH] Amun Sobek Ra Eil **:AUTOGRAPH/:COPYCLAIM-~DATE-03-~June-~2018**

:C.-S.-S.-C.-P.-S.-G.-
FLAG OF THIS
DOCUMENT-
CONTRACT-POSTAL-
VESSEL-COURT-
VENUE.

:Alexander-George:Middleditch:
:copy-right/copy-claim:

~1 For my KNOWLEDGE of the C.-S.-S.-C.-P.-S.-G are with these CLAIMS of the GEOMETRIC-LEVEL-FIELD on the LAND of the CONTRACT by this LIVE-LIFE-CLAIMANT-AUTOGRAPH-SEAL-COPYRIGHT/COPYCLAIM:

:Alexander-George:Middleditch.
:Live-life-claim:AF-2629-8493-7GB
~2:DATE~ 4th ~ July ~ 2020.

:C.-S.-S.-C.-P.-S.-G.-
FLAG OF THIS
DOCUMENT-
CONTRACT-POSTAL-
VESSEL-COURT-
VENUE.


: David-Wynn: Miller. :FEDERAL-POSTAL-JUDGE, :SPECIAL-DUTY
: PLENIPOTENTIARY-JUDGE, :AMBASSADOR, :POSTMASTER,
: U.N. SOVEREIGN
: FLAG OF THE CORRECT-SENTENCE-STRUCTURE-COMMUNICATION-PARSE-SYNTAX-GRAMMAR WITH THE CONTRACTING-PERSONS OF A CONTRACT-POSTAL-CORPORATION-VENUE
~ MILWAUKEE ~ WISCONSIN ~ 53218
:PHONE ~ 414-466-3584, :CELL ~ 414-803-5448
:email: DWMLAWPRO@AOL.COM
:web: WWW.DWMLC.COM

Flag of the Unity-States of the America

Title: 4: U.S.A. Codes: Chapter: 1: Section: 1&2 and under
Presidential: Executive-Order: #10834, dated August the 25 of 1959.

Preserves Constitution

Union = 40% of fly

Fly (width) = 1.9 x Hoist (height)

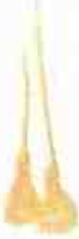
Union hoist = 7/13 (.5385x1)

Hoist (height) = 1

OFFICIAL FLAG of the UNITED: STATES OF THE AMERICA

National:flags authorized in Title: 4: U.S.A. Codes: Chapter: 1: Part:II: Section: 22-25: Part:III: Section: 31&32 are those used by the executive branch of the government. They represent government not individual citizens.

A yellow fringe is not authorized on a Title: 4: U.S.A. Codes: Chapter: 1: Sec.: 1&2 flag. It is a mutilation (Sec.:3).



Gold Tassel Admiralty

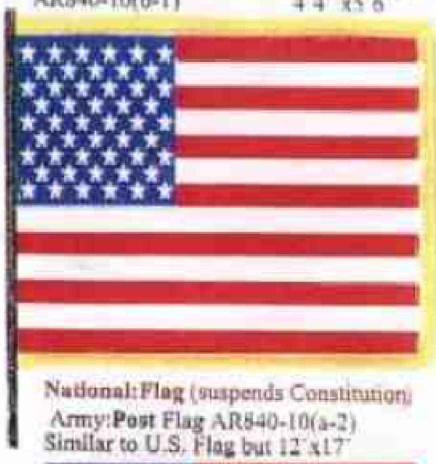
This Flag, with yellow fringe, represents No nation and No constitution.

National:Flag (suspends Constitution)
Army:**Ceremonial** and **Parade:**Flag
AR840-10(b-1) 4'4"x5'6"

Gold Ball Recruiting

Gold Spire Court-martial

Gold Eagle President, U.S.A.



National:Flag (suspends Constitution)
Army:**Post Flag** AR840-10(a-2)
Similar to U.S. Flag but 12'x17'

National Flag:(suspends Constitution)
Army:**Boat Flag** AR840-10(a-6)
3' hoist by 4' fly

OUR FLAG

There is only one, official, United: States flag which preserves the rights protected by the U.S.A. Constitution. Under it <u>you are innocent</u> until proven guilty.

National flags are government flags. They do not preserve the U.S.A. Constitutional rights. (<u>You are guilty</u> until proven innocent under them.)

Our flag is red, white and blue (no yellow).

Official State Flag

Desecrated State Flag